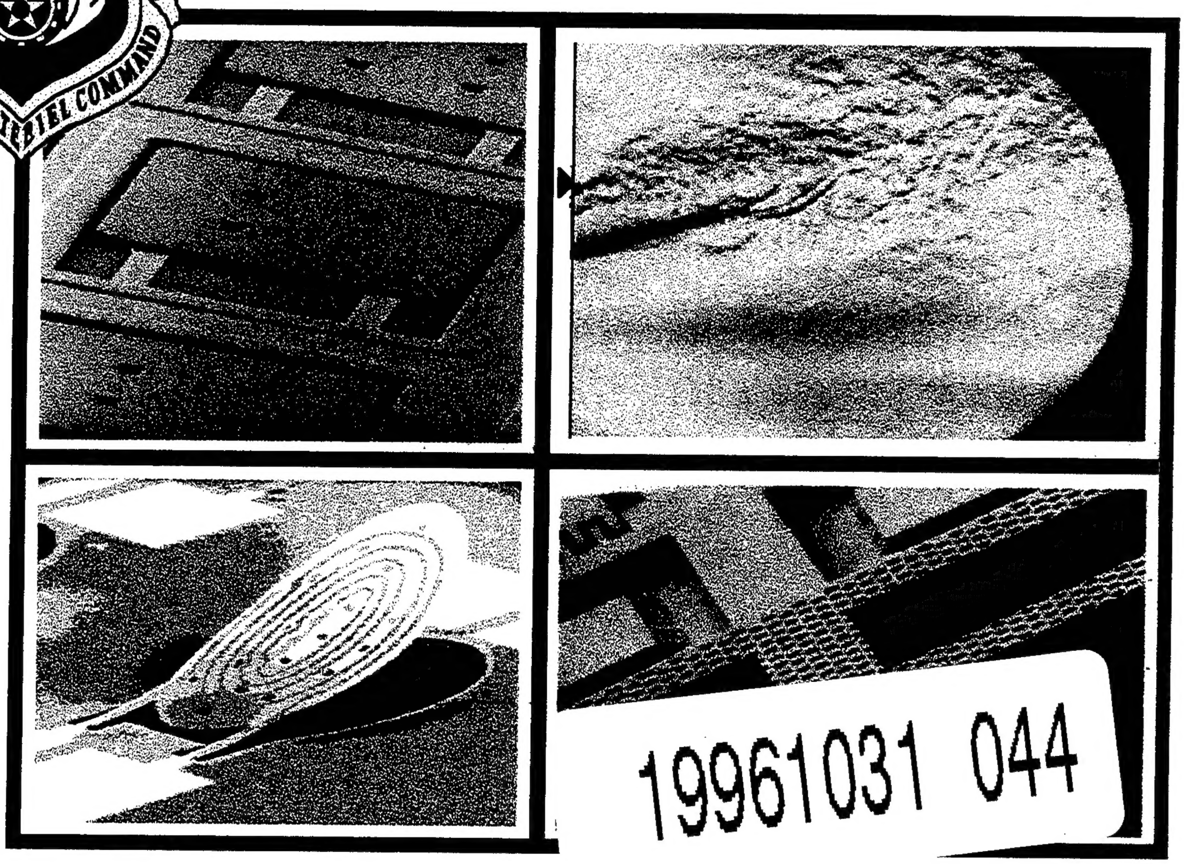
FY 97
RESEARCH
TECHNOLOGY AREA PLAN



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HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE AND TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE, OH

Note: This Research Technology Area Plan (TAP) is a planning document for the FY97 Science and Technology (S&T) program and is based on the President's FY97 Budget Request. It does not reflect the impact of the FY97 Congressional appropriations and FY97 budget actions. You should consult AFOSR/XPP, DSN 297-5015 or Commercial (202) 767-5015, for specific impacts that the FY97 appropriation may have had with regard to the contents of this particular TAP. Additional copies of the Research TAP and other Air Force TAPs are now available on the world wide web (letters are case sensitive) at http://www.afmc.wpafb.af.mil:12000/STBBS/info/taps/taps.htm. This document is current as of 1 May 1997.

Cover Picture: The Air Force Office of Scientific Research (AFOSR), has for several years been exploring an emerging technology called MEMS (Microfabricated Electro-Mechanical Systems) to achieve active control of aerodynamic flows for potential applications in fluidic thrust vectoring, drag reduction, high-lift, and noise reduction. The basic idea is to excite fundamental vorticity generation processes at the flow boundaries. The tiny, micromachined flap actuators shown are typically a few tenths of a millimeter in overall length and are activated by magnetic or electric fields. Illustrating one potential application, the 12 millimeter air jet at the upper right is shown in a vectored state (about 30 degrees upward from the horizontal). This is achieved by adding to the primary jet, a conventionally fabricated, one-half millimeter wide control jet whose location is indicated by the black triangle above the main jet nozzle. Similar sized, micro-fabricated jets are now being explored for jet vectoring, electronic cooling and other applications. This research would provide warfighters with flight vehicles having lighter weight flight control systems, providing greater range, payload and maneuverability. Research is being conducted by Caltech, UCLA, Georgia Tech, Illinois Institute of Technology and the University of Michigan. For further information contact Dr James McMichael at AFOSR, (202) 767-4936.

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The research technology area plan encompasses Air Force basic research. It includes all scientific and engineering disciplines contributing to the Air Force mission. The basic research outlined in this plan will enable the Air Force to perform its mission far into the 21st Century.

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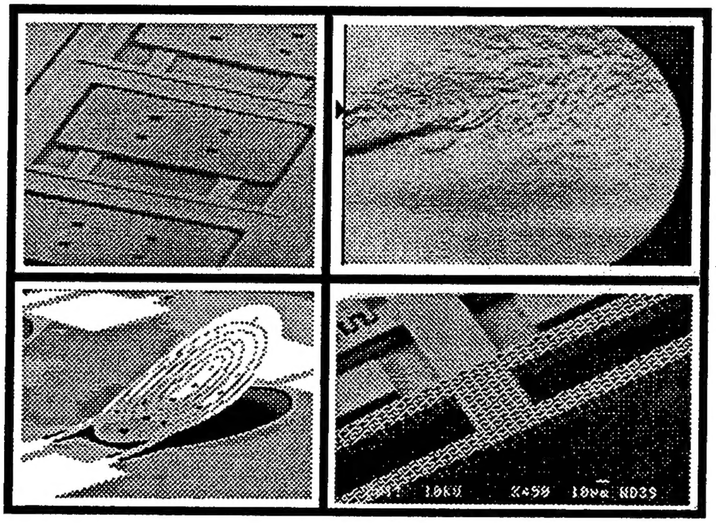
RESEARCH



VISIONS AND OPPORTUNITIES

The mission of Air Force basic research is to sponsor and sustain basic research, to transfer and transition research results, and to support Air Force goals of control and maximum utilization of air and space.

Only a vigorous, focused, and diversified basic research program can provide our nation with the required depth and scope of options for new and advanced technologies to meet the air and space superiority goals of the Air Force. Furthermore, the relative decrease in planned acquisition of new weapon systems makes it imperative to build a partnership with the U.S. industrial base, logistics support and the operational Air Force. This partnership helps to keep the focus of basic research on the warfighter needs, near- and long-term, and provides a quick transition path to current and future systems produced by industry.

To this end, Air Force basic research has adopted the vision to build partnerships with excellence and relevance. Its key ingredients are technology transition partnerships and laboratory partnerships. Their objective is to increase success and speed of technology transfer and transition while maintaining our long-standing tradition of quality research. Our partnership approach fosters integration of Air Force, university and industry researchers with customers in acquisition, the operational Air Force and U.S. industry, and most importantly, the in-house 6.1 tasks at the Air Force laboratories that are intensely connected with the 6.2 and 6.3 efforts within these laboratories. Laboratory partnerships are the cornerstone which enables the in-house component to become focal points for technology transition from the extramural research community. Last

year, results from over 1,500 active research tasks produced more than 400 significant technology transitions to Air Force 6.2/6.3 programs, to U.S. industry and to other customers within and outside of DoD.

Of critical long-term importance to the Air Force as well as the Nation are programs aimed at enhancing our most precious resource--human talent. These programs focus on the development of new technical research talent and the introduction of existing extramural talent to Air Force research interests. This includes provisions for undergraduate and graduate student research, fellowships for graduate students, and postdoctoral assignments at Air Force laboratories. In addition, university faculty are sponsored in summer programs as well as for sabbaticals at Air Force laboratories. Furthermore, Air Force researchers visit and work at highly reputed laboratories in the U.S. and overseas as part of this program. Strong emphasis is given to assure full participation of minorities and minority institutions in these efforts. Our interface with the international science and technology community through our offices in London, UK, and Tokyo, Japan allows the Air Force to leverage foreign research investments through access to and in collaboration with foreign laboratories and researchers.

This Technology Area Plan (TAP) reflects AFOSR's commitment to preserve and strengthen the national knowledge base and research infrastructure in support of the Air Force goals of global reach and global power. We produce world-class, militarily significant and commercially viable technology advances; we leverage the Air Force science and technology investment; and we transition research results to users in the Air Force through U.S. industry.

This plan has been reviewed by all Air Force Laboratory commanders and directors, and it reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.

Richard R. Paul

RICHARD R. PAUL
Major General, USAF
Technology Executive Officer

Robert L. Herklotz

ROBERT L. HERKLOTZ
Colonel, USAF
Commander, Air Force Office of Scientific Research

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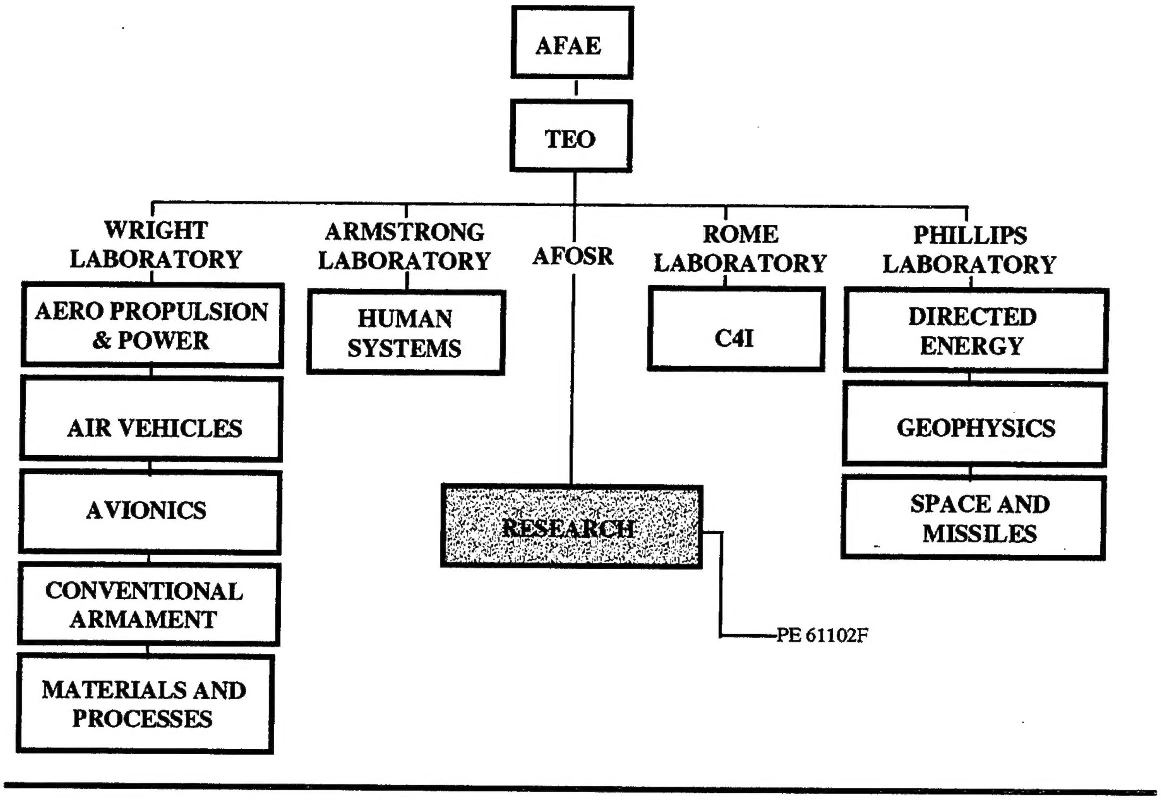


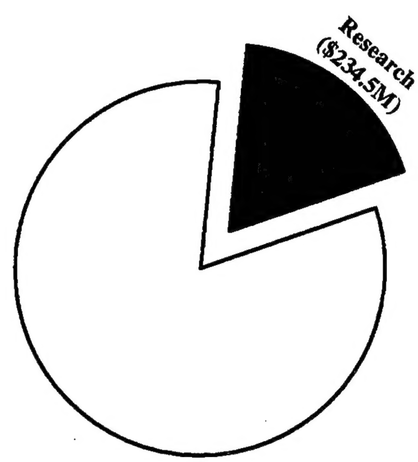
Figure 1. Air Force S&T Program Structure.

INTRODUCTION

BACKGROUND

The research technology area plan encompasses Air Force (AF) basic research. It includes all scientific and engineering disciplines contributing to the Air Force mission. The basic research outlined in this plan will enable the Air Force to perform its mission far into the 21st century. The research technology area's goals are to:

- maintain technological superiority in the areas relevant to Air Force needs
- prevent technological surprise to our Nation and create it for our adversaries
- maintain a strong research infrastructure of universities, U.S. industry and Air Force laboratories
- complement the national research effort, and
- transfer and transition research results to users and customers



Estimated AF S&T Budget for FY 1997: $1.272B

Figure 2. Research S&T vs AF S&T.

With its proud tradition of over 40 years, the Air Force Office of Scientific Research (AFOSR) is charged with directing the Air Force's basic research program. Through grants to universities, contracts for industry research, and support for basic research in Air Force laboratories, the AFOSR forges the base of future Air Force strength. These research programs, funded at about $224.2 million for FY 96, consist of approximately 1400 extramural grants and contracts to about 450 academic institutions, industrial firms, and government laboratories, as well as about 115 intramural research efforts in the four Air Force laboratories.

Our support of basic research has not only served Air Force goals directly, but also contributed to a wide spectrum of scientific breakthroughs: during the past 40 years, the Air Force has provided basic research funds to more than 20 U.S. researchers who, as a result of the funded work, were later awarded Nobel Prizes.

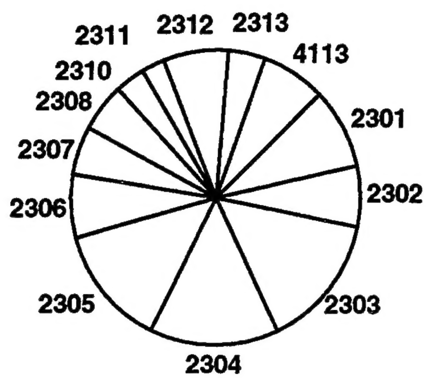
AFOSR-sponsored research has led to many technology breakthroughs that have had immediate impact on the requirements of the warfighter. Some examples of these important contributions include a nickel aluminide alloy (NiAl) which was successfully tested for use in fabricating turbine vanes for the Joint Turbine Advanced Gas Generator (JTAGG) engine. NiAl is a potential replacement material for the nickel-based superalloys currently in use at temperatures in excess of 1200 degrees Centigrade. Compared to nickel-based superalloys, NiAl intermetallic alloys weigh 30 percent less, and provide better oxidation resistance and four to eight times greater thermal conductivity, and will greatly enhance engine performance. AFOSR has supported research development for engineering tools that will help to evaluate and improve the structural integrity of the Air Force's aging fleet of aircraft. A novel experimental method was developed that simulates operational fretting fatigue through the use of an accurate finite-element model that can calculate stress, strain and displacement fields induced by fretting. Results of this research will help engineers characterize aircraft materials wear during operational service. Another recent achievement includes the development of new multi-color polymers that have the potential for use in Air Force fighter jet canopies. This technology will allow rapid control of brightness inside fighter cockpits during maneuvering above and below clouds, substantially prolonging the lifetime of cockpit display devices which will become viewable at much lower intensities than today's high intensity devices. AFOSR-sponsored research has also led to the recent development of ultrasensitive sensors to detect minute quantities of water vapor and other gases. Laser researchers at Phillips Laboratory and contractors at Airborne Laser are now using these sensors to improve the output power and efficiency of the Chemical Oxygen Iodine Laser (COIL), selected for use in the Airborne Laser demonstrator program. NASA is also using these sensors to measure mass flows for controlling the performance of jet engines.

The basic research program is divided into twelve scientific projects and one educational project. Table 1 shows these project designations and titles.

Project	Title
2301	Physics
2302	Solid Mechanics and Structures
2303	Chemistry
2304	Mathematical and Computer Sciences
2305	Electronics
2306	Structural Materials
2307	Fluid Mechanics
2308	Propulsion
2310	Atmospheric Sciences
2311	Space Sciences
2312	Biological Sciences
2313	Human Performance
4113	Science and Engineering Education Programs

Table 1. AFOSR's Research Projects

The relative distribution of Air Force basic research funds for these projects is shown in Figure 3 based on the FY 97 President's Budget Request. The program described in this TAP is subject to change based on Congressional action.



Estimated Research S&T Funding
for FY 1997: $234.5M

Figure 3. Major research thrusts (projects)

Other agencies such as the Defense Advanced Research Projects Agency (DARPA), the Ballistic Missile Defense Organization (BMDO), the Office of the Secretary of Defense (OSD), and Small Business Innovative Research (SBIR), provide additional resources for basic research. They are fully integrated into the programs described in this TAP and ensure a broad scope and critical mass for Air Force basic research programs.

AFOSR has identified 15 Core Technologies of importance to the Air Force. AFOSR Core Technologies are defined as those technologies where AFOSR has made substantial investments and where AFOSR-sponsored research is critical, leading, or even dominant on a national scale. For each Core Technology, the scientific disciplines and research issues that need to be addressed to advance the core technology have been linked with the customers, users, and beneficiaries of the core technology. In view of the complexities (many disciplines, very different customers) and the nonlinear nature of these linkages (6.1 often feeding directly into operations), the Core Technologies are the AFOSR basic research taxonomy for making management, priority and investment decisions. We believe that only technology advances (not just discipline advances) provide tangible customer benefits.

AFOSR Core Technologies

Structural Integrity
Structural Materials
Airbreathing Propulsion
Rocket and Space Propulsion
Aerodynamics and Hypersonics
Real Time Avionics
Optical Computing and Storage
Optical Countermeasures
Signatures and Surveillance
Precision Strike
High Power Microwaves
Space Weather Prediction
Hazard-Free Operations and Maintenance
Intelligent Systems for Selection and Training
Sustained Human Performance

Core Technologies thus represent AFOSR's approach to manage technology advances through coordinated research in several disciplines for the benefit of our customers; they represent the road maps for basic research.

The AFOSR works with the Air Force laboratories and the Headquarters Air Force Materiel Command to ensure research is integrated within the whole Air Force S&T program, and that it is responsive to current and future Air Force and Defense needs. AFOSR also works with the Office of the Director, Defense Research and Engineering (ODDR&E), other Services, Defense Advanced Research Projects Agency (DARPA), and the Ballistic Missile Defense Organization (BMDO), as well as other Federal agencies that sponsor research in technical areas of Air Force interest, to ensure programs are coordinated, complementary, and leverage each other.

DEFENSE RESEARCH: The ODDR&E, other Services, DARPA, and BMDO jointly plan and coordinate the Defense Department's basic research efforts through The Defense Committee on Research (DCOR). As the Air Force's single manager for basic research, AFOSR is a member of the DCOR and ensures Air Force research is integrated with the remainder of Defense research. Joint Scientific Planning Groups (SPGs) are organized around the major defense science areas to ensure the integration of the Services' and agencies' research programs in these areas.

Annually, as part of Defense research, AFOSR undergoes a DoD-wide Technology Area Review and Assessment (TARA), which provides feedback and guidance for AFOSR planning.

RESEARCH IN AIR FORCE LABORATORIES: Approximately one-third of our research program is carried out in Air Force laboratories: Armstrong, Phillips, Rome, and Wright. These intramural basic research programs contribute significantly to the Air Force's, as well as the Nation's, research efforts. One-third of the intramural research teams have been identified as leaders within the international community in fields of research. Through our concept of Laboratory Partnerships the intramural efforts enable effective transitioning of research results from the extramural research programs and the national and international research community to the Air Force 6.2 and 6.3 science and technology programs, and to the system program offices and logistics centers. In addition, intramural basic research attracts and retains world-class scientists and engineers. Thus, this intramural basic research investment provides the Air Force substantial benefits and leverage:

- World-class contributions to the Nation's research base.
- Talent pool for future Air Force technology leaders and managers.
- A training site for future scientific talent through high school, undergraduate, and graduate students.
- Interface with the national and international community through sponsorship of visiting scientists, guest professors, and workshops.
- Transition conduit for extramural research to the Air Force and its industrial suppliers from the national and international science and engineering communities.

In FY 97, the Air Force plans to significantly increase the research carried out in the Air Force laboratories. This increase will be in two areas. First, research identified by HQ AFMC needed to support increased emphasis and focus on technology needs to support aging aircraft, space, information dominance, and training the warfighter. Second, research identified by the Air Force Scientific Advisory Board (SAB) New World Vistas Study needed to support future Air Force capabilities and technologies.

Intense interaction between AFOSR's research program management and the S&T thrusts performed in the Air Force laboratories assures relevance and timely response to Air Force needs. Formal feedback, generated during reviews in the fall and spring of each year, is used to determine the direction of our research, and to enhance the transition to DoD 6.2 and 6.3 efforts, as well as directly to U.S. industry.

RESEARCH IN INDUSTRY: Industry, especially the aerospace industry, interacts with Air Force basic research in several ways:

Streamlining to compete in the global economy, U.S. companies have drastically cut research expenditures. Interface to Air Force sponsored university research and the Air Force laboratories now, more than ever, provides U.S. industry with access to new opportunities as well as with information helpful in addressing Air Force technology needs and opportunities. AFOSR maintains this interface through workshop participation with industry and by providing U.S. industry access to our research results.

Instituted in FY 95 by the Director of AFOSR, the Partnerships for Research Excellence and Transition (PRET) was designed to sponsor research at colleges and universities that has immediate significance to the industrial community. This ongoing program is designed to broaden private sector support of research relevant to Air Force interests and to facilitate transitioning of Air Force related knowledge to the private sector.

In FY 96, 3.5 percent of Air Force basic research funding directly supported basic research performed by U.S. industry. These efforts allow access to unique facilities, laboratory capabilities and special skills of industrial research teams. AFOSR's management of contracted research emphasizes corporate support through integration of research efforts into the contractors' planning process. This active approach to technology transfer stimulates interest in Independent Research

and Development (IR&D) among firms with little or no research involvement and leverages industrial basic research programs that might otherwise not respond to long term Air Force needs.

SMALL BUSINESS INNOVATIVE RESEARCH (SBIR). The AFOSR budget for SBIR projects will decrease from $7.5M in FY 96 to $7.3M in FY 97. The program will continue to focus on Phase II projects that have potential for commercialization. The goal is to convert 60 percent of the current Phase I projects to Phase II projects this year. The Small Business Technology Transfer Program (STTR), which was established by Congress in FY 94, remains stable. The STTR program funds research performed by a partnership that includes a small research firm and a research institution. In FY 97, $2.6M of the $7.3M identified in the SBIR program will be available for grants under the STTR program. The STTR program emphasizes projects with commercial potential. The STTR program, like the SBIR program, is a two phase program with one exception. STTR Phase I awards are up to $100K for a 12 month effort and Phase II awards are up to $500K for a 24 month effort. Over the next year, we are expecting our role in STTR to increase significantly.

RESEARCH OVERSEAS: Today a large portion of research advances occur overseas, although, on a per capita basis, the United States continues to lead the world. Since 1990, overseas inventors, mostly European and Japanese, have filed approximately 42 percent of all new U.S. patents.

To fulfill its mandate of assuring future technological superiority, the Air Force basic research program must respond to these developments and provide effective access to research advances overseas. To this end, AFOSR maintains foreign offices in London, UK, (the European Office of Aerospace Research and Development) and in Tokyo, Japan (the Asian Office of Aerospace Research and Development) which act as catalysts for increased cooperation in research and technology between Air Force laboratories and foreign scientists. Both offices are staffed with senior researchers drawn from the Air Force S&T community. In addition to a number of liaison activities, the primary focus of these offices is collaboration and technology transitioning. Their customers, historically the Air Force laboratories, increasingly include the logistics and test community and other Air Force and DoD agencies. Their means of fostering collaboration and technology transition include participation in the scientific and engineering communities of all nations at meetings, workshops, and seminars; detailed technical reporting, as well as analysis, and summary reports; and briefings and seminars at Air Force organizations. Special programs bring hundreds of eminent researchers from foreign laboratories to Air Force and DoD organizations for lectures, seminars, and other technical visits. A special program executes small, one-year "seed contracts" with foreign research institutes in technologies of particularly high interest to Air Force laboratories to form partnerships that will last beyond the individual contract. Another permits senior Air Force researchers to perform studies at leading foreign universities and laboratories. These latter programs provide access to advanced foreign techniques for Air Force laboratory efforts.

MINORITY PROGRAMS: For Historically Black Colleges and Universities (HBCU) and Minority Institutions (MI), two significant programs continue into FY 97. The first program is the Future Aerospace Science and Technology (FAST) Centers which is a part of a DoD infrastructure support program designed to help develop research and development capabilities at HBCU/MIs. The technique is to provide a critical mass of resources over a sustained period to develop true centers of technical excellence. Six areas of interest were selected and are currently being funded: 1) Fault-Tolerant Distributed Computing for Command Control Communications and Intelligence (C3I), 2) Cryoelectronic Signal Processing, 3) Lightweight Structural Materials and Processing, 4) Structural Integrity of Aerospace Systems, 5) Environmental Remediation, Fate and Transport of Hazardous Chemicals, and 6) Infrared (IR) Surveillance and Countermeasures. Each institution will be supported over a six year period subject to availability of funds. Second, AFOSR is currently funding the Navajo Community College (NCC), in conjunction with NASA. The program provides infrastructure support in the area of telecommunications to increase the capability of NCC in the area of science and technology. The Navajo drylands environmental facility is part of

the NCC system and may provide useful research for the Air Force because of Air Force facilities located in arid regions.

CHANGES FROM LAST YEAR

Project 2301 - Physics, was restructured to address the Imaging Physics subarea, to include unconventional imaging materials; adaptive optics: atmospheric turbulence; smart sensors and sensor fusion; and fundamental imaging physics.

Project 2303, Chemistry - restructured the area of Polymer Chemistry, to include electronic and optical polymers; polymer blends and copolymers; liquid crystals and liquid crystalline polymers; and organic nanostructures. The area of Chemical Reactivity and Synthesis was also restructured to address safe alternative materials; functional biomimetics; and long-life coatings. Surface Science subarea addresses electrochemistry and surface chemistry.

Project 2305 - Electronics, The Semiconductor Materials subarea was reorganized to address novel substrate technology, and the Electromagnetic Materials subarea reorganized to address nitrogen-based compound semiconductors.

Project 2307 - Fluid Mechanics, reorganized the Turbulence and Internal Flows subarea, to include active flow control for jet vectoring, mixing, high-lift and drag reduction; MEMS-based sensors, actuators, and systems for flow control; unsteady separation and flight controls; compressor instabilities, forced response and high-cycle fatigue; turbulent heat transfer and turbine cooling; and turbulence modeling, mixing and transport.

Project 2308 - Propulsion, The Propulsion Diagnostics subarea was eliminated, while effort in Space Power and Propulsion, and Air-Breathing Combustion increased.

Project 2309 - Terrestrial Sciences, was discontinued in accordance with OSD direction to transfer ongoing Air Force seismic research efforts from the Air Force basic research program to the Arms Control Implementation Program, PE 35145F.

Project 2310 - Atmospheric Sciences subarea Ionospheric Research was renamed Upper Atmosphere. The program was recently consolidated to combine upper atmospheric optical research with ionospheric research under one umbrella.

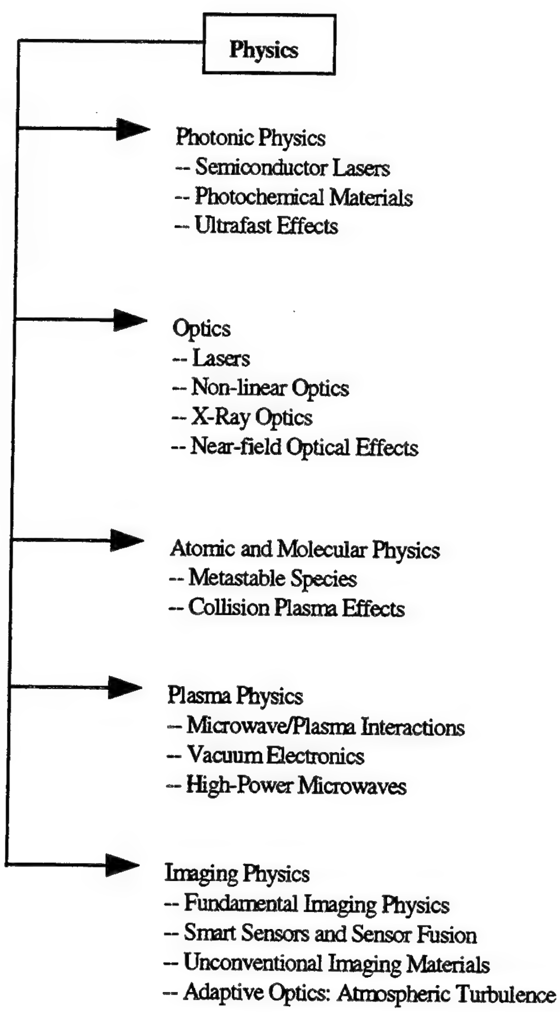
Project 2312 - Within the Bioenvironmental Sciences area Environmental Toxicology was renamed Chemical Toxicology which is a broder term and can include both the human and environmentally related toxicology research that AFOSR currently supports.

Project 2313 - Human Performance, Within the Sensory Systems subarea, speech recognition and pattern recognition were supplemented with biological sensors. Individual differences was renamed individual differences prediction in the Perception and Cognition subarea.

PROGRAM DESCRIPTION

PROJECT 2301, PHYSICS

Physics research continues to establish the underlying science foundations of critical Air Force topics listed in New World Vistas, AFMC Emphasis and Focus Areas as well as in the DoD Strategic Research Objectives. It also establishes the basis for many additional technologies such as avionics, aerospace and propulsion. Research in physics has often found application in fields of electronics and related technologies: e.g., performance improvements of lasers have carried over into propulsion system diagnostics or atmospheric study tools; into industrial semiconductor processing or Air Force medical applications. While the users and customers may differ, fundamental principles underlying desired functionality are the same and require detailed understanding to model and predict performance goals. The physics program is jointly planned and executed within the three Services and is coordinated with DARPA. Results of these well integrated efforts have transitioned to industry. At a recent blind trial at Tinker AFB, a new portable instrument for nondestructive detection of subsurface corrosion, developed with AFOSR funding at Iowa State University, was cited as one of only two instruments having produced sufficiently reliable results on tests of KC-135 aircraft.



Photonic physics aims to make available semiconductor lasers and laser arrays with characteristics needed in optical information storage and display (large area and helmet mounted), in wideband communication systems, in manufacturing inspection systems, and in medical diagnostics. High power arrays for threat countermeasures are also a major goal. Other major goals of this program are to advance electronic technology to speeds several orders of magnitude beyond what is available today, and to create new beam processing technologies that can lead to dramatic advances in microelectronics and micromechanics. Customers are the technology programs at the Wright, Rome, and Phillips Laboratories. Coordination with other services and DARPA, and industrial interaction are maintained by the mechanisms described above.

A major technology goal of the optics research is to find lasers, other than semiconductor lasers, exhibiting power, efficiency, wavelength, beam quality, and modulation formats that satisfy future Air Force requirements in the general areas of threat countermeasures, materials fabrication, and information processing and storage. Another major goal is to devise nonlinear optical techniques and devices for high power laser beam delivery, automatic target tracking, and conversion of laser wavelengths to values required for countermeasures. A third

goal is new fabrication, diagnostic, and testing tools for electronic and photonic systems, especially using advances in x-ray optics for x-ray imaging and beam formation and in near field scanning optical microscopy. Customers for these programs in laser and electro-optical technical development, and in optical and infrared countermeasures are the Wright and Phillips Laboratories. Coordination with other services and DARPA is maintained by serving on joint review panels or, by joint funding, for example at Hughes and Rockwell. DARPA's Optoelectronic Materials Research Centers serve as major technology coordination and transfer mechanisms. These provide formal technology demonstrations and industrial collaborations for numerous results achieved by AFOSR funded research.

Atomic and molecular physics research is directed toward understanding the interactions of atoms and molecules related to time and frequency physics and to upper atmosphere modeling. Accurate models of interatomic interactions will be used to make GPS clocks smaller and more accurate. Improved data and modeling capabilities will permit prediction of upper atmospheric processes affecting communications, surveillance, and remote sensing from space. This latter program has helped to establish reliable levels of background emission and demonstrate the imaging capability that is to be used in the Space and Missile Systems Center's (SMC) Defense Meteorological Satellite Program. Data on etchant species have been provided to revise industrial plasma reactor models (SEMATECH).

Plasma physics seeks fundamental understanding of collective interactions of charged particles with electromagnetic fields in order to drive advances in communications, radar, low-observables, materials processing, and directed energy weapons. A major theme in this subarea is the push for more efficient, compact, tunable, and reliable electron-beam-driven sources of microwave radiation. In satisfying the needs of Rome and Wright Laboratories, this program emphasizes sources offering higher frequencies and broader bandwidth. A key element of this research effort is the Center for the Advanced Thermionic Research Initiative located at the University of California at Davis. That center, along with other university efforts, boasts extremely strong ties with major U.S. microwave electronics firms such as Varian Associates and Litton Electron Devices. This university/industry cross-fertilization is further enhanced through close cooperative ties to the Navy's program in Vacuum Electronics. An additional major beneficiary of the above research efforts is the high power microwave (HPM) weapons-related R&D efforts studied jointly with the Phillips Laboratory. Additional research thrusts examine the effects of plasma on microwave signals and novel concepts related to the use of atmospheric-pressure plasmas in industrial materials processing.

Research in imaging physics addresses the theoretical and experimental bottlenecks impeding the exploitation of advanced imaging technologies for the Joint Warfighter. Fundamental issues concerning the image formation and propagation processes are addressed. Physical and mathematical problems in image inversion/reconstruction, inverse scattering, and electromagnetic wave generation/propagation in various media are of interest. Distributed detector systems, multi-featured sensors, and multi-spectral methods are investigated with regards to smart processing and sensor fusion for global situational awareness. Providing real-time response to the battlefield commander evokes interest in integrated parallelization of devices, supporting software, and the chosen target recognition/feature extraction paradigm. Neural network imaging controllers, feature based statistical estimation methods, and the electronic emulation of biological vision systems are investigated to provide fast and accurate information as opposed to raw data to the battlefield commander. Novel unconventional imaging methods to optimally recover images in the presence of atmospheric turbulence are investigated for both active (non-illuminated) and passive (naturally illuminated) imaging systems. Emphasis is placed on a 24 hour, all weather, high resolution capability of imaging Low Earth Orbit (LEO) or geosynchronous (GEO) satellites.

PROJECT 2302, SOLID MECHANICS AND STRUCTURES

This project seeks to develop a fundamental understanding of the behavior of aerospace materials, structures, and supporting facilities, leading to the cost-effective development and safe, reliable operation of superior weapons and defensive systems. Research includes such diverse topics as the micromechanical design of advanced materials, modeling and simulation of the dynamic behavior of aircraft, missiles, and large space structures, and the technology integration for the performance and survivability enhancement of these systems.

Solid Mechanics and Structures

Mechanics of Materials
-- High Temperature Composite Materials
-- Fracture Behavior of Materials
-- Ceramic-Matrix Composites
-- Internal Damage Growth Mechanics

Particulate Mechanics
-- Effects of Microstructures
-- Constitutive Behavior of Particulate Systems
-- Shear Localization and Instability
-- Flow in Porous Media

Structural Mechanics
-- Mechanics of Deformation and Damage
-- Aeroelasticity System Behavior
-- Structure-Control Integration
-- Active Structures

Future aerospace engine and airframe structures will be composed of advanced, high-temperature composite materials capable of extended operation in severe environments. The development of these materials will allow the design of faster, more efficient aircraft and spacecraft. These advanced materials are also enabling technology for planned hypersonic weapons and aircraft, which can potentially take off from conventional runways and achieve global orbit. Current project thrusts include understanding the fracture behavior and thermomechanical behavior of ceramic-matrix composites, metal-matrix composites, high-temperature polymer-matrix composites, carbon-carbon composites, intermetallics, and structural ceramics. Scientific issues include improved fiber/matrix interfaces, durable coating systems, and improved design methodology and life prediction systems based on material damage growth mechanisms. Results from this program are being used by Boeing Helicopters to design fuselage stiffeners made from textile structural composite materials, and to develop biaxial failure models for polymer-matrix composites to be used in low-temperature sections of Pratt and Whitney Aircraft turbine engines. AFOSR researchers are also studying innovative new material systems, such as functionally-graded materials and nanostructural materials.

The goal of the particulate mechanics research program is to develop a first principles understanding of the behavior of particulate systems and their interaction with the surrounding environment. The first principle thrust focuses on understanding the mechanical behavior of multiphase particulate systems. Particulate materials are defined as those that can be represented as an assemblage of physically discrete particles - either alone or in a matrix material having significantly different properties. Particulate materials of interest include soils, rock, concrete, and asphalt. The specific research objectives are to understand: 1) the influence of material microstructure on overall constitutive behavior; 2) the constitutive behavior of multiphase (heterogeneous) particulate systems; and 3) the localization and instability in particulate media, including their potential to flow and liquefy.

Particulate mechanics research examines particulate systems with characteristic lengths that range from nanometers to meters. Efforts seek to obtain quantitative relationships to describe the fundamental mechanics governing the behavior of particulate systems. For example, the behavior between individual constituents and between the aggregate assembly and the surrounding environment in response to an external load. Efforts involve interdisciplinary theoretical, analytical and/or experimental approaches from disciplines such as

mechanics, material science, physics and applied mathematics. Constitutive models that incorporate the microstructural behavior of these heterogeneous anisotropic multiphase discrete systems are theorized and experimentally demonstrated.

Particulate materials are ubiquitous, hence the research products from this program will have a scientific impact on a diverse range of end users. This research will provide a knowledge base from which analytical models can be developed to design and evaluate new material processing technologies, and hence, more affordable aerospace structural materials. Direct benefits to the military services include real-time damage assessment on the battle field, improved weapons effectiveness, enhanced structural survivability and vulnerability and "smart" infrastructure supporting systems. Much of the technology supporting these needs has been based on empiricism. Therefore, the scientific contribution of this program will be a physically based understanding of the behavior of a range of materials and analysis techniques to predict their response to new loading regimes.

The anisotrophy, inhomogeneity, and damage characteristics of emerging structural material systems dictate the development of new solid mechanics and structural analysis principles critical for performance prediction and material synthesis. Traditional mechanics of materials principles do not capture the fundamentals that dictate the behavior of these advanced material systems. One aspect of the structural mechanics program is to expand the fundamental knowledge base to better understand the mechanics of deformation and damage of aerospace structures. Phillips Laboratory has successfully used the fracture mechanics methodologies developed at the University of Illinois to assess the fracture behavior of rate sensitive materials (i.e., solid propellants used in rocket motors). The extended service life for many existing systems also requires further research to understand how materials and structures behave after very long periods of service. Factors such as corrosion and multiple-site damage serve to reduce the load-carrying capability of aging Air Force aircraft. Engineers at the McDonnell Douglas Aircraft Company are using methods developed by researchers at Purdue University for analysis of bonded composite repairs on metallic airframe structures. New methods of nondestructive evaluation (NDE) of these systems are also being sought to detect internal cracking and/or corrosion in a quick and reliable manner. The mechanics research sponsored in this project is closely coordinated with research performed under Project 2306, Structural Materials, which considers the materials science processing aspects of modern aerospace structural material systems.

Another goal of this project is to obtain an understanding of the aeroelastic and acoustic behavior of airframe and engine structures and the dynamic behavior of launch vehicles and space structures. Nonlinearities in these systems are traced to the interaction of fluids and structures, large amplitude vibration, system nonlinearity due to damping, and other phenomenon. This research is expected to provide engineering information on airframe failure from fluid flow disturbances and engine stall due to pressure variation. In fact, results of this research have been used by Pratt and Whitney to predict and control the aeroelastic characteristics of gas turbine engine compressor blades. This research also seeks to provide answers to many system operational issues. Examples include limit cycle oscillations and flutter on fixed-wing aircraft, engine compressor instability and turbine failure, and spacecraft vibration and control. Researchers in the universities are working with Wright Laboratory and the Aeronautical Systems Center (ASC) on these operational problems.

Structure control integration involves coupling nonlinear dynamics principles with advanced materials development, fluid mechanics, control theory, and sensor/actuator development. This research will lead to the development and design of real-time monitoring and self-correction techniques for enhancing system performance. For example, intelligent materials and active structures are being developed which can continuously monitor damage formation and growth in current and future aerospace structures. Continuous shape control of aerodynamic

surfaces may also be possible through the placement of systems of sensors and actuators at critical points within the structure.

In summary, research in solid mechanics and structures is necessary for the design and operation of future Air Force weapon systems, as well as the continuing operation of existing systems, which are currently projected for use well beyond their original design lifetimes. Under Reliance, the Air Force has the lead responsibility for the mechanics of high-temperature structural materials and particulate material systems and fixed-wing aeroelasticity. The Army has primary responsibility for research in impact/penetration mechanics, and rotary-wing aeroelasticity, while the Navy is the lead service in the mechanics of thick-section composites, structural acoustics, and hydroelasticity. Project 2302, then, provides the only direct DoD 6.1 mechanics and structures technology support to the design and operations of USAF aircraft, missiles, and spacecraft.

PROJECT 2303, CHEMISTRY

Research in chemistry fills current and projected requirements of two principal Air Force technologies: materials and energetics. This project provides the fundamental knowledge needed to meet the increasing demands for materials with advanced properties, affordable cost, and environmentally benign processing. Achieving the required material properties, such as strength, durability, toughness, service temperature and lifetime, spectral response, and corrosion resistance, increasingly requires control of structure and composition at small levels, sometimes approaching fewer than hundreds of atoms and molecules. Areas of emphasis in materials chemistry include properties and processing of polymers, corrosion resistance, friction and wear, and the chemical and biochemical transformations which aerospace materials undergo in the environment.

The technology of energetics seeks to efficiently control the conversion of one form of energy to another. Transformation of stored chemical energy finds application in propulsion, munitions, lasers, and as a source of signatures of aircraft and spacecraft. Advances in space propulsion are sought by developing materials with high energy density and controllable stability. Research on molecular energy redistribution in condensed, inhomogeneous systems will produce effective, but insensitive, explosives for safe storage. The detection and surveillance of space systems are achieved through the understanding of the detailed light emitting chemical reactions in the exhaust plume in comparison with counterpart reactions of the background atmosphere.

Chemistry

Surface Science
-- Tribology
-- Chemical Sensors
-- Electrochemistry
-- Surface Chemistry

Polymer Chemistry
-- Electronic and Optical Polymers
-- Polymer Blends and Copolymers
-- Liquid Crystals and Liquid Crystalline Polymers
-- Organic Nanostructures

Chemical Reactivity and Synthesis
-- Safe Alternative Materials & Processes
-- Functional Biomimetics
-- Long-Life Coatings

Molecular Dynamics
-- Atmospheric Chemistry
-- Energetic Materials
-- Chemical Lasers
-- Interactive Dynamics

Theoretical Chemistry
-- Molecular Structure and Properties
-- Reaction Dynamics

The scientific areas in surface science include tribochemistry, chemical sensors, electrochemistry, and surface chemistry. This research will provide the Air Force technological pay-offs in novel lubricants and lubrication systems, coatings for space vehicles, corrosion research targeted for the aging fleet of aircraft, and compact power sources for use in satellites, aircraft, communications, and survival gear. This

work supports technology requirements of the Armstrong (chemical sensors), Phillips (inorganic polymers), Rome (surface chemistry), and Wright (tribology, corrosion science, and electrochemistry) Laboratories. In-house research is conducted at two of the four laboratories in the areas of lubrication research and inorganic polymers. This program supports subterranean sensing for the Air Force environmental clean up program with its chemical sensor effort. Significant technology transfers in the past year included the production of polyhedral oligomeric silsesquioxane (POSS) polymers for Thiokol Corporation's rocket motor insulation. Recent experimental work supported by this program shows a step doubling of Ni (977) crystal surfaces in the presence of small amounts of oxygen immediately prior to bulk oxidation which is now being transferred to use in aluminum surfaces. This may lead to diagnostic tools to alert technicians to impending corrosion on aircraft and how stress relates to corrosion, and thereby prevent its occurrence. Transfer of tribology technology includes advanced coatings for ball bearings, dental drills, and plating applications and the development of new lubricating systems for engine wear applications.

Polymer chemistry seeks to advance the organic and polymeric materials technologies by providing the knowledge needed to create new properties for Air Force applications and to utilize the materials in a manner that will yield more durable and affordable systems. This research supports both functional applications such as photonics and electronics and structural applications such as aircraft and rocket components. The knowledge generated in this work is continuously transitioned into development programs of Wright Laboratory, DARPA and BMDO, and supports requirements of Wright, Rome, and Phillips Laboratories. Research in polymer chemistry includes extramural research and in-house research at Phillips and Wright Laboratories. This work focuses in four areas: active electronic and optical polymers, polymer blends and copolymers, liquid crystals and liquid crystalline polymers, and organic nanostructures. Polymers with active electronic and optical properties are needed for many advanced Air Force applications in electronics and photonics. This area supports applications such as communications, signal processing and high information content displays. The polymer blends and copolymers program is focused on controlling the nano- to micro-scale phase separation and the influence of morphologies on electronic and mechanical properties of the polymers. The liquid crystals and liquid crystalline polymers program addresses the self assembly behavior of these materials and their influence on polymer properties. The results of these two areas will not only be relevant to optical and electronic applications such as laser hardening; they will be useful for structural applications such as toughened materials for canopy, aircraft and rocket components. The organic nanostructure research will advance the capability to create and manipulate nanostructures. These capabilities can be useful for applications such as high-density data storage.

Research in chemical reactivity and synthesis investigates current materials and processes that are hazardous to the environment, such as fire suppression agents and deicing chemicals, in order to provide technology for safer alternatives without sacrificing properties or cost. Research on functional biomimetics seeks to understand the optimized materials design and process mechanisms in living organisms to incorporate their advantages into materials such as lightweight, uncooled infrared sensors and ambient temperature fabrication of tailored optoelectronic materials. A new research initiative area includes an integrated study of chemistry issues associated with polymeric aircraft coatings such as environmental degradation, adhesion, safe application, selective removal, coloration, and role in corrosion protection in order to provide novel technology for longer life and lower maintenance costs for aging aircraft.

Research in molecular dynamics and theoretical chemistry aims at developing predictive capabilities for chemical reactivity and energy transfer processes and controlling these processes on a detailed molecular level. These capabilities will improve aircraft and rocket propulsion

system design, detection and control of signatures and exhausts from aerospace vehicles, energetic materials for propellants and explosives, and high energy laser systems. The basic understanding developed here is transitioned to applied programs by close interactions between principal investigators, Air Force laboratory scientists, and representatives of industry. For example, the High Energy Density Matter program, run jointly with the Phillips Laboratory, studies energy storage and stability of molecules in order to produce novel propellants for spacelift.

Theoretical chemistry research has saved time and research money by eliminating trial-and-error synthesis of proposed HEDM materials which lack promise. Novel propellant additives developed in this program are currently being tested in collaboration with industry. Research is also exploring how energy localization affects chemical reactions in solids that control the sensitivity of explosives. Studies of the dynamics of ion-molecule reactions, reactions of atmospheric species, energy transfer, and gas-surface interactions support efforts to improve our understanding of processes that produce radiant emissions in the atmosphere; affect communications, plumes, and signatures; and degrade materials in space. Research results are transitioned to many areas including predictive codes for radar cross sections (RCS) (REACH), models of atmospheric radiance (FAUST, MODTRAN), spacecraft interactions (SOCRATES), and chemical lasers. Efforts to develop infrared chemical lasers for Air Force applications are carried out with Phillips Laboratory.

PROJECT 2304, MATHEMATICAL AND COMPUTER SCIENCES

This project provides advances in the mathematical and computer sciences that increase our capability to model, analyze, understand, and control complex systems and phenomena of Air Force interest and also increase our capability to utilize computing effectively. Requirements are ubiquitous throughout the Air Force as reliance on software and automation becomes widespread both in embedded applications, simulation and training, and for engineering design, and as requirements for increased systems performance drive us into more nonlinear and complex domains.

Our program in dynamics and control has the Tri-Services leadership role as well as a high level of national recognition. Research is leading to improved techniques in the design and analysis of new control systems with enhanced capabilities and performance. Applications include the development of robust feedback controllers for advanced high performance aircraft with new capabilities for battle damage mitigation, maneuverability and engine stall avoidance; the control of vibrations and the shape of large, flexible space structures; active control of wing camber using embedded smart sensors and actuators; and the control of combustion and fluid flow processes associated with aerospace vehicles.

Research emphasizes distributed parameter control, robust multivariable feedback control, and adaptive control. Recently, novel interdisciplinary research has been initiated in nonlinear control to develop techniques for controlling fluid flow and combustion processes, as well as highly nonlinear coupled interactions between structural deformations and unsteady flows. Fundamental theoretical algorithms developed in this program have transitioned to Wright Laboratory as well as other industries and DoD laboratories.

Research in physical mathematics pursues the development and interrogation of accurate mathematical models (mostly nonlinear partial differential equations) in a diverse collection of Air Force important areas including nonlinear optics (an area of Tri-Service leadership), materials science, inverse problems, and theoretical fluid dynamics. Equations describing electromagnetic wave propagation in nonlinear media are predicting stable operating regimes of semiconductor laser diode arrays. These lasers-on-a-chip can produce a substantial beam if properly orchestrated so that chaotic flickering and associated interference can be avoided. This work is in support of laser research at the Phillips

Laboratory. Similarly, for mathematics of materials, the nonlinear variational problems whose minima correspond to stable configurations of novel composite media and shape memory alloys have ushered in a new era in material descriptions and predictions.

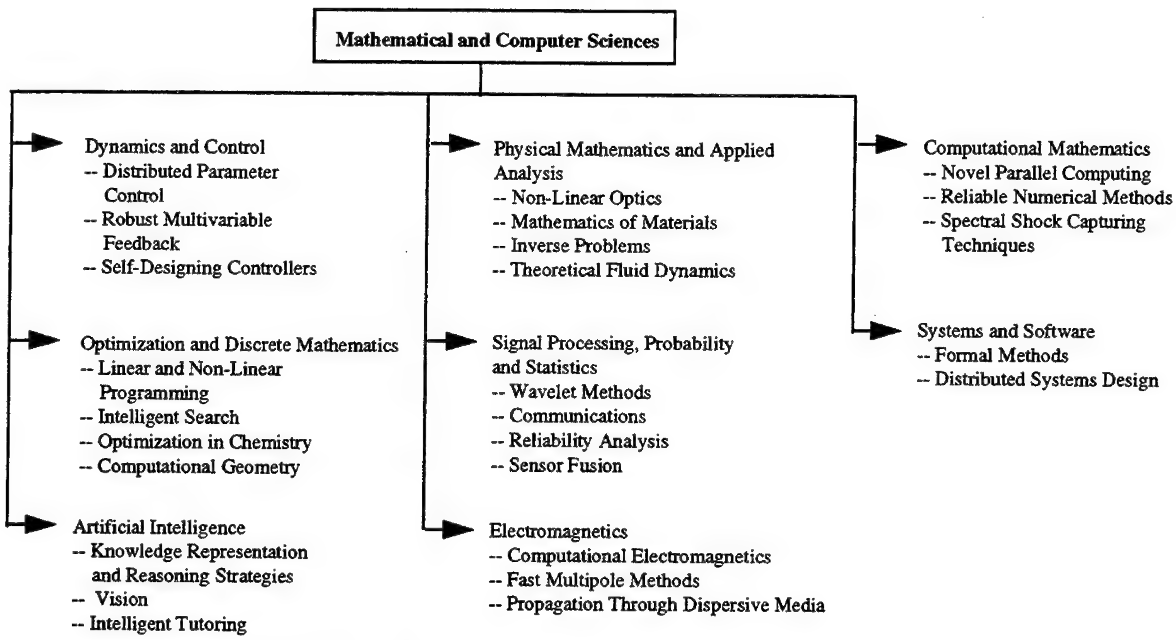
Smart skins and other useful designer materials are being explored at Wright Laboratory. The Air Force's emphasis on reliability and maintainability relies on credible and affordable inspection. The mathematics of inverse problems speaks to these goals by identifying what is interpretable and by delivering stable, accurate numerics. An example of theoretical fluid dynamics research which impacts Air Force and the civilian world is the elimination of wind tunnel wall interference effects during transonic test conditions. In contrast to both subsonic and supersonic tests, the wall interference is more grievous (test conditions can be encountered which correspond to no real flight conditions and the culprit is the tunnel wall) and the mathematical model is much more challenging.

Research in computational mathematics develops improved mathematical methods and algorithms to support Air Force scientific computing interests. It concentrates on supporting innovative methods and algorithms which enable the improved modeling, simulation, understanding, and control of complex physical phenomena. These phenomena include fluid flow, combustion processes, control of flexible space structures, nonlinear optics, directed energy weapons, high energy-density materials, crystal growth, and mesoscale weather modeling. Research in this subarea supports the national agenda in high-performance computing, including the exploitation of parallel computing. New and improved numerical methods are being developed including homogenization techniques, continuation methods, finite elements, particle and vortex methods, finite difference methods, ENO methods, spectral methods, and computational linear algebra, especially multigrid techniques. Recent progress in nonlinear dynamical systems, wavelets, and multigrid research is enabling us to develop new parallel multiresolution (or multiscale) algorithms with the capability for estimating the effects of neglected scales on those which are accounted for, in order to accurately predict the approximate long-time dynamics of a variety of dissipative systems of nonlinear partial differential equations (such as Navier-Stokes) over a broad range of physical scales, and to dramatically reduce the costs for computer simulations. New efforts are underway to develop modeling and analysis methods as well as numerical techniques needed to bring combustion processes into warhead design problems.

Mathematical methods in optimization and discrete mathematics are directed toward the solution of large or complex problems such as those occurring in logistics, engineering design, or strategic planning. When applied to Air Force transportation systems, these techniques result in the more efficient movement of men and material. We are also applying them to physical systems, specifically to the determination of molecular structures. This will enable prediction of material properties and the design of new materials. New efforts are underway in the control of discrete event dynamic systems. These systems are used to model both theater battle management and manufacturing operations. In the latter area, we expect to transition results directly to the manufacture of titanium aluminide rotor blades at Wright Laboratory.

Research in statistical theory and in the treatment of transmitted information (signal processing) is pursued with the goal of improving communications, imaging, and the performance of systems. Among the new mathematical approaches that have been beneficial in communications (for identifying features in covert signals and compression of data in terrain-following links), and imaging (target recognition, advanced beam forming) is the wavelet transform and its generalizations. AFOSR has sustained an early lead in Federal and world levels in this technology. Nonlinear science is also producing an impact with chaotic systems that generate covert signals, and in the design of robust inexpensive analog to digital converters. Important progress has been made in extending imaging capability to a wide spectral range, including Synthetic Aperture Radar (SAR) and

millimeter wave, as well as the use of multi-resolution methods for modeling background, terrain (which helps one quickly spot moving vehicles). Combined sensing (such as laser-radar/FLIR) necessitates advanced statistical methods ("sensor fusion") for their rapid interpretation, critical to maintaining an edge in air combat. The integrity of mechanical/ electronic systems and people-based organizations can be assured only through testing and statistics. New methodologies in reliability analysis are continuing to prove their worth, and the Bayesian approach, together with algebraic experimental design, makes it possible to get the most for every dollar spent on life testing of critical systems. AFOTEC, responsible for the certification of reliable Air Force systems, has been implementing significant findings from research in this area.



With the Air Force's increasing reliance on computers, it is important to develop systems that are efficient and reliable. Research into formal methods for software engineering addresses this concern. Formal methods involve the use of mathematics and logic as the primary element of software engineering; for example, using mathematical notation to specify the desired software product. This provides for the possibility of automatic (or semi-automatic) translation of the mathematical specification into executable code. One approach, tested at the U.S. Transportation Command, automatically generated transportation scheduling requirements from the Time-Phased Force and Deployment Data significantly faster than conventional scheduling systems. The growing importance of C^3I has resulted in a greater need for effective distributed processing systems for sharing information and computing resources. This program has Tri-Service leadership in distributed computing. Such research into real-time distributed systems provides means to effectively manage the complex interconnected military environment. A new initiative is aimed at developing dramatic improvements in command and control through the dynamic interplay between data processing and signal processing technologies.

Artificial intelligence research is pursued to enable the timely management of information and to enable decision making based on that information. The key issue that we are addressing is how to effectively incorporate all available information, from diverse sources and modalities, into the decision process. To understand this issue, we are sponsoring research that looks for ways to make the best use of uncertain information, share and disseminate information, increase accuracy, speed, and economy of the recognition and identification

process, and aid the intelligence analyst. The program concentrates on research needed to develop large-scale intelligent systems that can address practical Air Force needs. To that end we seek means to scale up those methods that work for small knowledge-based systems. We need to overcome present limitations in the amount of knowledge employed due to knowledge acquisition and management deficiencies. Present limitations on meaningful systems adaptation and improvement with use also needs to be overcome. Formalisms need to be developed for the representation of and reasoning with uncertainty, handling corrupt information, and effectively utilizing experiences. To aid the information analyst in fusing information from a diverse modality of sources, we seek means to combine numeric and symbolic inference methods. We seek ways to integrate probabilistic reasoning methods with traditional formal logic methods, and perhaps with other forms of computation. Qualitative methods which will drastically simplify computation and increase performance robustness are also of interest. We are seeking to develop technology that will provide support to decision making. To that end, research is needed to develop intelligent agents capable of gathering information, reducing data to manageable amount of essential information, and cooperating with other agents to solve problems. Research is also needed to combine artificial intelligence methods with operations research tools to overcome inefficiencies in solving some mission critical Air Force problems such as scheduling in a distributed, dynamic environment. The vision and image-understanding research within this program concentrates on solving those problems that interfere with the building of robust, accurate and timely recognition systems. Research is directed toward the development of context-based image-databases needed by the Air Force for time-critical and resource-bound operating conditions. The research is also directed toward applications such as surveillance, object recognition, target identification, cartography, scene interpretation from image streams, and the fusion of multi-sensor inputs. Research in object and scene interpretation from sensors using the visual, infrared, and radio frequency bands of the electromagnetic spectrum includes context-based, geometric-model-based, deformable-model-based, and physics-based approaches and the application of theories of invariants. Intelligent tutoring is an area of increased interest to the Air Force. The focus of this effort is to develop efficient computer mediated tools for instructional delivery both for training and tutoring with the objective of reducing manpower needs and optimize tutoring and training. Adaptive teaching systems which model the trainee, and attempt to understand his responses by simulating these models, is one area supported within this program. Research tasks in intelligent tutoring are linked to the Human Resource Laboratory of the Armstrong Laboratory for the portion of effort which involves evaluation and experimentation with actual trainees.

Electromagnetics research ensures effective exploitation of electromagnetic waves and devices. Propagation studies emphasize characterization of inhomogeneous and/or dispersive media with a description of the behavior of waves in such media. Propagation through dispersive media is being pursued in support of occupation and environmental health issues because human tissue is dispersive and rational attempts to determine microwave exposure standards must incorporate this propagation in penetration codes. The investment in electromagnetic scattering is driven by Air Force requirements in both target acquisition and detection avoidance. In the area of computational electromagnetics, large scale scattering computation, such as fast multipole methods, is necessary for appraisal radar coverage (theirs and ours) if realistic topography and atmospheric conditions (refraction) are accounted for. Also, prediction of the radar cross section for design or identification purposes requires extensive, and rapid computation. A new initiative in high-power microwave will improve our modeling capabilities for both wide band and narrow band source design.

PROJECT 2305, ELECTRONICS

Research in electronics supports a broad community of high technology customers in the fields of surveillance, communication and precision weapons. It provides the fundamental

basis for improving or developing future generations of Air Force electronic systems consistent with the SAB New World Vistas Topics, the AFMC Emphases and the DoD Strategic Research Objectives. Specifically, goals of this program are to use the entire electromagnetic spectrum for improving transmission bandwidth and data storage; to increase data and information processing speed in semiconductor, photonic, and superconducting systems for faster decision making; and to firmly control complexity, reliability and affordability. Intramural research in this program is carried out to a substantial part at the Phillips, Rome, and Wright Laboratories, and aims at the discovery of innovative design options. Research results are transitioned to the user community in the Air Force or to industry under Air Force contract. The Air Force and other services closely coordinate and plan research in electronics through the Joint Services Electronics Program and the Electronics Scientific Planning Group. The Air Force also leverages DARPA investments to support Air Force goals in areas such as high temperature electronics. The Joint Services Electronics Program (JSEP), a mutual enterprise of the Army, Navy, and Air Force in existence since 1946, is designed to provide the Department of Defense with a university-based research capability in electronics sciences and information sciences, and electromagnetic research in an interactive, interdisciplinary environment with strong emphasis on local related areas. The objective is to support high risk, long-range, pioneering science in the areas of solid state electronics, quantum electronics, leadership and minimal governmental oversight; to build productive partnerships between universities, U.S. industries, and DoD. Of twelve JSEP universities, the Air Force supports five with a strong emphasis on optical signal processing for global awareness, space operations, and information dominance.

Research in electronic devices concentrates on approaches which promise one or more of the following: greater frequency/speed of operation, greater bandwidth, lower power consumption, lower noise, higher rf power output, and greater reliability in support of Air Force needs in guidance, surveillance, communications, electronic countermeasures, and electronic warfare. These approaches fall into two categories: the application of new semiconductor materials to existing electronic devices, and the development of entirely new devices and material concepts.

The focus of electronic components and circuits is the development of new and improved materials and components supporting such advanced Air Force systems as millimeter circuits and IR imaging systems. Important drivers are higher frequency of operation, higher power output, the integration into monolithic integrated circuits and improved reliability.

Research in semiconductor materials is directed toward developing advanced electronic and optoelectronic materials with emphasis on growth and characterization of novel semiconductor compounds and heterostructures, radiation interactions, and reliability problems associated with solid state devices. Efforts will develop new materials for equilibrium and non-equilibrium growth techniques for structures with applications in digital and microwave devices; high temperature electronics; ultraviolet to infrared detectors; solid-state and semiconductor lasers; waveguides; and displays and emitters. The major theme includes an atomistic, solid-state physics based understanding of the materials science associated with such topics as heteroepitaxy, growth, and defects.

Work on electromagnetic materials focuses on interactions of light with semiconductors. Crystalline nonlinear materials and modulation materials are of interest. Bulk crystal growth techniques continue to be developed. Semiconductor material research is aimed at optoelectronics (especially infrared) with emphasis on use in fast, efficient electromagnetic applications such as in space and global communications, command, and control.

Electronics

- Electronic Devices
  - -- Femtosecondary Processes in Semiconductors
  - -- Novel Transistor Concepts
- Semiconductor Materials
  - -- Low Temperature Film Growth
  - -- Ultrafast Laser Interaction
  - -- Wide Bandgap Materials
- Electronic Components and Circuits
  - -- MMWave Components and Circuits
  - -- Spatial and Spectral Modulation
  - -- Far-IR Imaging Systems
- Electromagnetic Materials
  - -- Crystalline Non-Linear Materials
  - -- Optoelectronic Materials
  - -- Detector Materials
- Optoelectronic Information Processing
  - -- Optical Storage Approaches
  - -- Optoelectronic Computation and Interconnects
- Quantum Electronic Solids
  - -- Superconducting Materials
  - -- Superconducting Magnetometry
  - -- Superconducting Electronics

Optoelectronic information processing research pursues the insertion of optical and optoelectronic techniques into information processing systems, the capabilities which range from parallel computing and image processing to signal processing. It supports device physics investigations that provide both the optical-electronic interface and the optical-environmental interface. Optical and optoelectronic devices perform data acquisition, transmission, interconnect switching, and memory functions and support efforts in the use of photonics to achieve real-time adaptive signal and image processing capabilities.

The major thrust in quantum electronic solids is to create new superconducting and other electronic material structures to enhance the ability to sense and manipulate observable information. The great virtue of superconducting electronics is that it can carry out the necessary functions faster, more sensitively, and with lower power dissipation--features which allow higher density of processing elements for a smaller instrument package. An adjunct to this program is the discovery of improved techniques for the nondestructive evaluation of aging aircraft.

PROJECT 2306, STRUCTURAL MATERIALS

This research provides the basic knowledge for development of new materials to improve the performance, life-cycle cost, and reliability of Air Force systems. Direct goals of this program are to supply advanced materials that will increase the thrust-to-weight ratios of engines, reduce the weight of aerospace vehicle structures while increasing their performance and control, and eliminate advanced materials reliability issues. Emphasis is on monolithic metals, intermetallics and ceramics; composites including matrices of metal, intermetallic, ceramic, and organic materials; and carbon-carbon materials. This program studies a broad range of material properties such as strength, toughness, fatigue resistance, and environmental resistance in airframe, turbine engine, and spacecraft applications. Research on processing methods is an integral component to the research on materials properties. This project directly supports the technology goals of the Wright Laboratory Materials Directorate. Extramural researchers closely coordinate with the four research tasks at this directorate and one research task at the Phillips Laboratory Propulsion Directorate. The efforts in this project are also related to research being performed in Project 2302, Solid Mechanics and Structures. Close coordination of this project with the entire DoD basic research program in structural materials is being maintained through Project Reliance. Several jointly sponsored programs have resulted from this coordination process. Additionally, close coordination is maintained with industry R&D counterparts including Dow Corning, McDonnell Douglas, Rockwell, General Electric, and United Technologies.

Structural Materials

- Metallic Structural Materials
  - Metallic Alloys used in Aerospace Applications
  - Alloy Theory, Design and Experimental Verification
  - Modeling and Processing of Interfaces in Metal Matrix Composites
  - Functionally Graded and Nanocrystalline Metallic Structural Materials
- Ceramics and Non-Metallic Structural Materials
  - Related Processing, Structures and Properties
  - Interface Control for Ceramic Matrix Composites
  - Fundamentals of Fracture and Creep
  - Oxidative Processes of Carbon-Carbon Materials
- Organic Matrix Composites
  - Environmental Effects on Polymer Matrix Composites
  - Processing Science of Organic Matrix Composites
  - Environmentally Safe Processing of Composites
  - Processing of Polymer Precursors

The goal of the research thrust in metallic structural materials is to provide the fundamental knowledge required for new metallic alloys and composites for aerospace applications. Potential applications of these materials will include turbine airfoils and disks, engine casings and nozzle components, airframe structural components, space and rocket propulsion components, and hypersonic vehicle skins. Improved metallic structural materials will be capable of higher operating temperatures at significantly reduced densities than currently available materials. These characteristics will result in increased thrust-to-weight ratios in gas turbine engines, lighter weight airframes, and will enable hypersonic vehicle technology. This includes development of materials to withstand temperatures up to and beyond 2400° F for turbine engines and hypersonic vehicle applications. This will be accomplished through an understanding of relationships between processing, chemistry, structure and properties of metallic materials. Specific scientific topics include the development and experimental verification of theoretical and computational (atomistic) models, phase transformations, interfacial phenomena, strengthening mechanisms, plasticity, creep, fatigue, environmental effects, and the dynamic and static fracture of structural metallic materials. Materials under research in the metallic structural materials thrust include lightweight alloys, refractory metals, intermetallic alloys, metal matrix composites, intermetallic matrix composites, nanocrystalline metallics, functionally graded materials, laminated microstructures, amorphous metallic alloys and protective metallic coating systems. Efforts will be expanded in the area of understanding the basic phenomena controlling the high cycle fatigue behavior of gas turbine engine alloys.

The objective of the ceramic materials research thrust is to provide scientific background for current and future applications of ceramics, ceramic-matrix composites, and carbon-based materials in Air Force systems. Ceramic materials are attractive for Air Force structural applications due to their capability to work at very high temperatures, their intense strength and stiffness, and their hardness that leads to excellent wear properties. Introduction of ceramic bearings in gas turbine engines and Ceramic Matrix Composites (CMC) for exhaust nozzles should lead to major improvements in thrust-to-weight ratio, efficiency, and signature characteristics of engines. In support of these applications, this program emphasizes fundamental studies of high temperature properties of ceramic materials and their relationship to the atomic structure of constituting phases and to microstructure of the materials. Of particular importance are studies of oxide materials with large complex unit cells giving rise to high creep resistance. Detailed studies of interfaces and interphases, their atomic structure, thermodynamic and mechanical characteristics, and their influence on the creep properties of ceramics are also major components of this program. Currently, the research effort in interfaces concentrates on control of interfaces between the fiber and matrix in ceramic matrix composites. The goal is to lay the foundation for the development of tough, reliable ceramic matrix composites capable of working at temperatures above 2700°F. A variety of techniques for controlling oxidation resistance, thermal stability, and shear strength of interfaces are currently under investigation. In the area of carbon-carbon composites the program concentrates on designing new approaches for oxidation protection, such as protective ceramic

films, oxidation-inhibiting dopants, and surface modifiers.

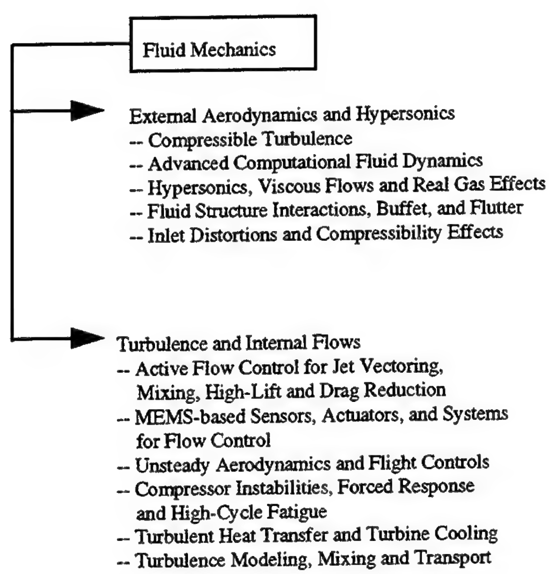
The goal of research in organic matrix composites is to provide the knowledge for lowering the life-cycle cost of using polymer matrix composites in Air Force systems. Additionally, improving the performance properties of these materials such as higher operating temperatures and improved compressive strengths after impact are important objectives. High temperature adhesives and processing of polymer precursors for carbon-carbon and ceramic structures are of interest to this program. The current program focuses on obtaining a better understanding of the mechanisms of property degradation in polymer matrix composites exposed to the environments. This knowledge is important to implementing effective countermeasures during processing and deployment to prevent or decelerate performance degradation, and in reliably and accurately predicting the service lives of composite structures. The chemical and physical changes of the matrices, fibers and their interfaces will be investigated individually and collectively in a composite configuration to provide a better understanding of their influence on the property changes of composite structures.

PROJECT 2307, FLUID MECHANICS

Air Force basic research in fluid mechanics seeks to enhance the performance and reliability of aerospace vehicles by developing new capabilities for predicting and controlling the fluid dynamic and thermodynamic behavior of complex flows in flight regimes and propulsion systems affecting Air Force operations. This research seeks to understand key physical phenomena, to develop methods and models to predict them, and to create innovative strategies to expand the boundaries of flight by controlling these phenomena.

Major thrusts include: 1) the development of computational methods for accurate and efficient numerical solution of the equations of fluid dynamics, especially for dynamic, unsteady, multi-body problems, 2) active flow control relevant to engine nozzle exhaust flows, mixing thrust vectoring, and high lift, 3) the aerothermodynamics of hypersonic flows, 4) the fundamental structure and dynamics of transitional and turbulent compressible flows, 5) the prediction and control of turbulence, and 6) the complex internal aerodynamics and thermodynamics of flows in gas turbine engines. These efforts are closely coupled with Air Force Laboratory 6.2 and 6.3 programs, primarily at the Wright Laboratory. This project provides fundamental knowledge, data, concepts and tools for aerodynamic and aerothermodynamic prediction, design, test, and support. It directly supports the research needs of industry as well as Air Force Laboratories, Test Centers and Logistics Centers.

Aircraft manufacturers, Air Force laboratories and test centers require improved, validated turbulence models. In fact, such models top the list of industry needs for fluid mechanics research and are a key pacing item for computational fluid dynamics. Research targets the high Reynolds number, compressible flows of interest to the Air Force, and seeks to develop large-eddy simulation (LES) methods and improved subgrid turbulence models for accurate predictions. Recent advances at Princeton University using renormalization group methods for turbulence models are now being used by Fluent Inc. and by Pratt and Whitney.



Aircraft and weapon systems in combat operate in environments far more hostile than those occurring under level flight. Weapons released in this environment have been known to hit the launch aircraft. Advanced Computational Fluid Dynamics (CFD) research is developing numerical simulation methods which predict the dynamic motion effects on aircraft systems and missiles. Research in multi-body CFD is developing computer simulation technology which can predict the trajectories of weapons as they release from an aircraft, reducing the danger to pilots who fly weapons certification tests. CFD research also focuses on understanding the fundamental causes of inlet unstart, the sudden shut down of engines on maneuvering supersonic and hypersonic vehicles. Results in advanced grid generation methods from research at Mississippi State University are now being used by McDonnell Douglas Aerospace in the F-15 program.

Future hypersonic flight vehicles will operate at very high altitudes within the earth's atmosphere to reach global targets. At these altitudes the atmosphere is highly rarefied, and there is no way to predict the character of these rarefied flows. Underpredicted drag and heat transfer can result in vehicles that will not reach their intended targets. Computational and experimental research aims at revealing the fundamental fluid mechanical properties of hypersonic, chemically reacting flow, providing better predictions of vehicle heating, directly leading to safe designs.

Active flow control research explores fundamental flow instabilities and their control for potential application to thrust vectoring, engine controls, high lift, aero-optics, low noise, and several other critical areas. Low observable requirements fix jet nozzle exit geometry and require internal flow adjustments to optimize performance. Fluidic flow controls are being explored in this context. Innovative active flow control approaches also enable the development of advanced high-lift technologies for enhanced aerodynamic performance of stealth vehicle configurations. Active flow control may also alleviate currently uncontrolled sonic fatigue problems with the divergent nozzle flaps; those on the F-110 engine create one of the major headaches for logistics support of the F-16. Also, inadequate turbulent drag reduction strategies limit the potential for enhanced range and payload. Basic research approaches under exploration include innovative uses of microelectromechanical systems (MEMS) and neural networks, the generic issue being the management and control of vorticity production on aerodynamic surfaces. McDonnell Douglas is now exploring basic research results on jet control for supersonic jet noise reduction, fluidically controlled thrust vectoring, and paint removal processes. Boeing is exploring new aerodynamic testing methods based on recent basic research on microfabricated flow sensors.

Maneuvering combat aircraft generate complex, 3-D spatially and temporally varying flows which are ingested by the propulsion system's airbreathing engine inlets. The total pressure distribution of these complex flows entering the inlets become even more non-uniform, or distorted, as the flow passes through the inlet compression shock wave system. This distortion greatly reduces the total pressure of the flow which enters the compressor face for supersonic propulsion and turbomachine engine propulsion systems. The greater the distortion, the lower the engine thrust. Computational fluid dynamic research has been undertaken to predict the complex distortion fields which arise in supersonic and hypersonic air breathing engine inlets and inlet systems on maneuvering Air Force aircraft and missile weapons systems.

A major concern of engine manufacturers, and the focus of the Integrated High Performance Turbine Engine Technology (IHPTET) Program is to improve the thrust to weight ratio of gas turbine engines. Improved compressor efficiency and stability are key elements of this requirement. Problems with heat transfer in the combustor and turbine stages account for half the ten-year development time currently required for new engines. In addition, thermally induced fatigue failures in the F-110 combustor produce one of the largest maintenance problems for the F-16. Research within this project aims at improving our understanding of heat transfer in high turbulence environments, improving film

cooling, and controlling the unsteady fluid dynamics dominating compressor performance and contributing to the problem of high-cycle fatigue.

Current flight control systems intentionally limit the operational envelope of modern fighters to avoid entering the post stall environment during dynamic maneuvers. Unsteady aerodynamics research within this project seeks to develop the knowledge base to expand the predictability and controllability of flows in this environment. Another critical need is preventing the unsteady aerodynamic buffeting of vertical control surfaces on the F-15 and F-16 which leads to structural fatigue, loss of reliability and degraded supportability.

Through Reliance, this research program is closely coordinated with Army and Navy programs. AFOSR fluid mechanics research focuses on central Air Force interests in high speed flows, compressibility, dynamic maneuverability, control of aerodynamic phenomena, and the fluid mechanics and thermodynamics of flow in gas turbine engines. In turn, the Navy focuses on hydrodynamic wakes and free surface phenomena. In the area of unsteady aerodynamics, the Army deals primarily with 2-D blade-rotor interactions relevant to helicopters, while the Air Force focuses on 3-D vortex dominated fluid-structure interactions relevant to aircraft maneuverability.

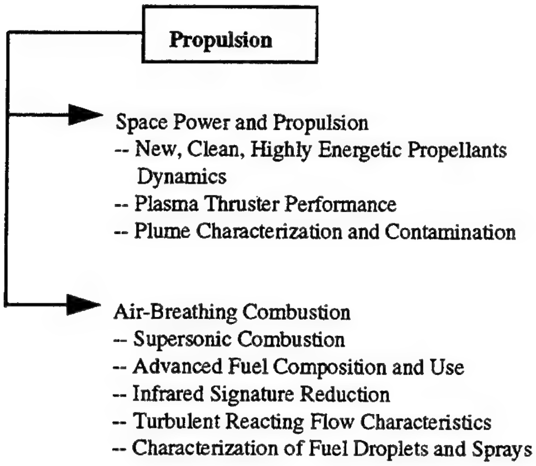
PROJECT 2308, PROPULSION

The propulsion project conducts research applicable to all military air and space vehicular systems, including aircraft, tactical and strategic missiles, space launch vehicles, space vehicles, and future hypersonic systems. Advances in propulsion and energy conversion technology are essential to the increase in range, payload, speed, stealth, and supportability and decreases in cost of either existing or new vehicular systems. The payoffs include a 100 percent increase in range/payload for attack aircraft, a Mach 3+ capability in F-15 size aircraft, a 200 percent increase in payload to geosynchronous earth orbit, plasma propulsion systems for small satellites less than 250 kg., and ramjet/scramjet operation to Mach 8-10 using hydrocarbon fuels.

Research falls into the areas of chemically reacting flow, non-chemical energetics, and diagnostics. The research effort is being conducted extramurally by both universities and industrial laboratories, such as those of United Technologies Corporation, McDonnell Douglas, and the General Electric Corporation and intramurally at Phillips and Wright Laboratories. Chemically reacting flows involve complex coupling between the rate of energy release through chemical reaction and the fluid processes which transport fuel, oxidizer, combustion products, and enthalpy. Non-chemical energetic systems include plasma propulsion for efficient, orbit-correction, maneuvering, and orbit-raising space missions. Diagnostics research provides critically needed measurement capability for developing fundamental understanding and performance characterization of these processes such as spray and solid propellant combustion and plasma propulsion. For example, the sharp peaks obtained in the elastic scattering spectrum from high quality, minimum light leakage optical cavity are used to obtain real-time droplet diameter information. This data is used extensively in injector design for both gas turbine and rocket industries. In addition, elastic scattering spectrum can be used as a diameter-determining template of optical communication fiber during the fiber-melt pulling process.

In terms of Air Force systems, research in this project falls into several major thrusts which are hypersonic air-breathing propulsion; future hydrocarbon fuel utilization; combustion chamber compatible, clean, highly energetic propellants; high voltage/high power solar array systems; longer life cycle, highly efficient low and high power plasma thrusters; and high performance heavy launch systems. This research will develop computational design capability and efficient novel testing techniques to replace costly and lengthy trial-and error propulsion system development methods. These new cost-effective design approaches will lead to improved performance, reduced maintenance time and costs, lower observables, and extended

lifetimes of propulsion systems on Air Force aircraft, missiles and spacecraft.



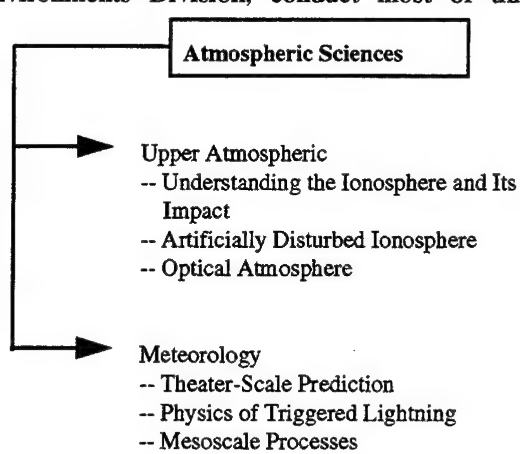
Upon request of the Arnold Engineering Development Center (AEDC), AFOSR extended research on plumes and signatures to include ultraviolet radiation. Enhanced efforts in soot reduction and control studies will increase engine performance and reduce aircraft signature and pollution. Research on turbulence-chemistry interactions in plumes is to seek chemical and fluid dynamic control mechanisms for improving signature characteristics and continue development of new, clean, highly energetic propellants with proper chamber and mechanistic compatibility to satisfy environmental concerns.

Rocket combustion instability is being investigated by looking at the interactions among propellant combustion, rocket chamber dynamics, and heat transfer. An important new research thrust is advanced fuel composition and combustion. Advanced engines may withstand higher operating temperatures by using fuel as a coolant. After heating to a supercritical thermodynamic state, the fuel will not behave like liquid or gas and may form solid residues which will clog vital fuel system components. Research addressing this includes fuel formulation and its supercritical mixing and combustion characteristics, and the source of solids formation. New measurement techniques to characterize fuel-air mixing in both air-breathing and rocket chemical propulsion systems are being developed. Their techniques are essential to interpret system performance and to provide quantitative data to test the accuracy of computational design methods.

PROJECT 2310, ATMOSPHERIC SCIENCES

The atmospheric sciences project provides the fundamental research needed to understand the.environment in which the Air Force operates. This improved understanding will lead to better precision-guided munitions, C3I, surveillance, and spacecraft reliability. The Air Force requirement for night/in-weather operational capability is not achievable without this fundamental understanding of atmospheric processes. Atmospheric properties such as wind, clouds, precipitation, ionization, and optical/infrared transmissivity all affect Air Force system performance. AFOSR sponsored research includes extramural contracts/grants and basic research programs at Phillips Laboratory. It emphasizes improved atmospheric prediction for enhanced tactical operations and atmospheric dynamics and impacts on communications and surveillance systems.

Upper atmospheric studies seek to improve C^3I, surveillance, and spacecraft reliability. Natural and artificial ionospheric disturbances, and optical phenomena can impact communications, degrade early warning systems, and decay spacecraft orbits. The Phillips Laboratory's Ionospheric Physics Division, and the Optical Environments Division, conduct most of this



research which benefits operational customers such as Air Force Space Command and the Air Force Space Forecasting Center (AFSFC). A new explanation for strong lower wave hybrid turbulence was developed by researchers at Phillips Laboratory which has the capability to predict regions of ionospheric disturbances.

Research also focuses on the physics and dynamics of the lower atmosphere. The ultimate goal is to improve atmospheric prediction in support of tactical and strategic forces. The Phillips Laboratory Atmospheric Sciences Division, (PL/GPA), conducts about one half of this research. Mesoscale weather prediction, boundary layer physics, cloud microphysics, and physics of triggered lightning comprise the main research interests. The Air Force's Weather System will take advantage of many discoveries in this subarea including recent efforts to integrate satellite data into mesoscale weather forecasting models. A tri-service program of research in atmospheric and space sciences is jointly planned through the Scientific Planning Group for Atmospheric and Space Sciences.

PROJECT 2311, SPACE SCIENCES

The Space Sciences project stimulates and supports basic research devoted to the Air Force mission of defending the United States through the control and exploitation of space. The Scientific Planning Group for Atmospheric and Space Sciences plans Tri-Service research programs in this area. The objective of space sciences is to define the space arena in support of present and future Air Force operations. Research in space sciences provides the basic knowledge of the particles and electromagnetic fields in near-Earth space, including solar dynamics and the interaction of particles and energy from the sun with the interplanetary medium and the Earth's magnetosphere. Solar radiation and charged atomic particles can damage and destroy Air Force spacecraft, disrupt the detection and tracking of missiles and satellites, distort communications, and interfere with surveillance operations. Space science research is critical to the development of future Air Weather Service space weather prediction models and future Air Force space surveillance systems. This project strives to understand geomagnetic storms arising from solar disturbances.

Space Sciences

Space Physics
-- Magnetospheric Model
-- Solar Activity
-- Space Weather Specification and Prediction
-- Space Surveillance
-- Active Space Experimentation

These solar disturbances are the major cause of blackouts in satellite communication systems. Unencumbered surveillance and communications require prediction and mitigation of the effects of solar emissions. Research involves both analytical and theoretical studies based on data collected from Earth-based observatories, satellite sensors, and active space experiments that seek to control the space environment. The Space Sciences project performs basic research at the Geophysics Directorate of the Phillips Laboratory and at universities throughout the United States. The hazard to space systems posed by energetic particles in the Earth's radiation belts continues to increase due to reliance on unhardened technologies and the potential of adversaries to increase trapped particle populations. Theoretical work to investigate active methods of reducing trapped particle populations will be undertaken.

PROJECT 2312, BIOLOGICAL SCIENCES

This project supports two major concerns of our Air Force technology areas: force readiness and environmental protection. Biological science research provides a fundamental understanding of the biological mechanisms regulating human performance, and the response of individuals and the environment to toxic agents. This understanding is required to develop strategies to improve human performance and to protect both personnel and the environment from hazardous agents utilized in Air Force operations. Research in this project is planned through the Tri-Service

Scientific Planning Groups for Biological Science, and Cognitive and Neurosciences.

Biological Sciences

- Bioenvironmental Sciences
  - -- Chemical Toxicology
  - -- Radiant Energy Bioeffects
  - -- Bioremediation
- Chronobiology and Neural Adaptation
  - -- Biochemistry of Stress
  - -- Circadian Timing System
  - -- Aircrew Performance and Fatigue Prediction
  - -- Brain Mechanisms
  - -- Neurobiology of Attention

Bioenvironmental sciences research seeks to understand fundamental mechanisms involved in assessing and predicting both the health and environmental hazards of Air Force chemicals and the occupational health hazards of laser and microwave radiation. Research in this area supports a number of Air Force customers, including the Air Force Center for Environmental Excellence (AFCEE), Air Combat Command (ACC), Air Mobility Command (AMC), Air Force Space Command (AFSPC), Air Force Materiel Command (AFMC), Air Force Surgeon Generals Office (AFSGO), and the Air Force Safety Center. Studies focus on constructing predictive models to assess health and environmental risks. Ultimately, this research will contribute to the development of rapid and accurate methods that may identify environmentally safe materials and technologies during the early stages of their design and development. Early knowledge of potential toxicity will better enable the Air Force to comply with environmental laws, protect the environment, and avoid wasting time and money on the scale up and manufacture of still more toxic materials. This research also provides a scientific base within the Air Force, enabling contributions to the risk assessment process for determining the environmental and health standards of Air Force-relevant materials. Research conducted in this area has strong dual-use applications. For example, ongoing work assessing the ocular effects of ultrashort laser pulses stands to benefit not just the Air Force but the medical fields of surgery and ophthalmology as well.

The bioenvironmental sciences program also includes a research thrust involving the biodegradation and detoxification of hazardous Air Force materials. This research examines microbiological, biochemical and molecular mechanisms required to optimize use of microbes to degrade hazardous materials such as jet fuels and missile propellants. A mechanistic understanding of biodegradation will enable the development and implementation of cost-effective and environmentally safe strategies for cleaning up contaminated Air Force bases. An anaerobic bacterium discovered by Air Force researchers is now being used by Envirogen, Inc., J.R. Simplot, Inc., and the EPA to degrade nitrogen-based explosive and propellant compounds. With possible dual-use applications in the recovery of usable manufacturing materials, this effort also supports Manufacturing Technology.

Chronobiology and Neural Adaptation. AFOSR supports basic research on the circadian timing system, the biology underlying fatigue including individual differences and performance prediction, the brain processes involved in regulating adaptation to changes-in-state, the neurobiology of attention and the biochemistry of stress. An understanding of these mechanisms will facilitate the development of pharmacological, photic and behavioral strategies for altering internal pacemaker function and ultimately alleviate the operational performance decrements associated with jet lag and night operations. Current experimental approaches include both human and animal behavior studies as well as biochemistry particularly neurochemistry, molecular biology, electrophysiology including lesion studies, neurophysiology, pharmacology. Data suggest that the circadian pacemaker contains a large population of autonomous, single-cell circadian oscillators and that synapses between these cells are neither necessary for this oscillation nor sufficient to synchronize them. Recent accomplishments include: 1) evidence that

serotonin is an important modulator of light input to the circadian pacemaker and possibly can be used to modify light effect on the biological clock, thereby helping aircrew adapt to night operations. 2) a demonstration that the subjective discomfort, fatigue, and decreased performance which occur following abrupt shifts of environmental time (often refereed to as the jet lag syndrome) are associated with both a desynchronization of bodily rhythms and also with a prolonged elevation of Thyroid Stimulating Hormone (TSH) in peripheral circulation, and 3) experiments restricting humans to five hours of sleep a night for seven consecutive days show a linear rather than exponential growth in fatigue across days, Results of this research will improve operator performance during sustained operations by promoting the development of fatigue and alertness management tools. The key Air Force customers of this research are the Air Force Special Operations Command (AFSOC), Air Combat Command (ACC), Air Mobility Command (AMC), and the USAF Safety Center.

PROJECT 2313, HUMAN PERFORMANCE

This project supports Air Force personnel readiness, and technology development for command and control and information systems, through a broad-based research program in Human Performance. Research in biological Sensory Systems contributes to technologies for image sensing and methods of information display best suited for human-system integration. Research in perception and cognition contributes to improved testing for personnel selection and classification, and the development of technologies to support both adaptive teams for Command and Control, and future workstations with embedded intelligent tutoring. This project is coordinated with other Services through the Cognitive and Neural Sciences panel of the tri-Service Scientific Planning Group.

Vision research supports the Air Force need to improve the effectiveness of visual displays, including camouflage, and to create novel systems for automated processing of image data. Researchers recently created and applied models of human contrast perception to problems of image quality measurement and camouflage. Models of retinal image processing derived from measures of neural circuitry in the retina are used to create novel integrated circuits for computer image processing.

Hearing research supports the Air Force need for secure error-free voice communication and improved human interface technologies that take advantage of automatic speech recognition and virtual environments. A model of acoustic signal encoding by vertebrates expresses a novel integrated circuit with potential use for hearing aids and related applications where signal shaping can increase intelligibility. A demonstrated neural network model of auditory localization can segment complex sound fields containing multiple sources. Cues to target location provided by novel 3-D audio devices improve visual search. These devices are now being tested for use by the ACC.

Biological sensor research supports the Air Force need to enhance auditory and visual recognition for human situational awareness. Investigation of the physical mechanisms by which in vivo systems accept, process, and transmit visual and auditory information is currently underway. Research in this area is designed to integrate man made sensors with biological sensors or identify new biological materials that may act alone to improve sensory systems available to air crews engaged in the task of target detection and recognition.

Human Performance

Sensory Systems
-- Human Image and Speech Processing
-- Biological Sensors
-- Multisensory Integration

Perception and Cognition
-- Cognitive and Psychomotor Modeling
-- Individual Differences Prediction
-- Human-Machine Interaction
-- Intelligent Tutoring Strategies

An understanding of multisensory integration is critical for the development of uninhabited air vehicles (UAVs), and is required to make the dynamic aviation environment safe by reducing the human sensory mismatches that result in pilot disorientation in aircraft accidents. The focus is on the integration of visual, vestibular, kinesthetic and proprioceptive information processing. Experimental and theoretical approaches involve the simultaneous examination of visual search patterns, the speed and accuracy of complex joint movements, and the underlying patterns of control necessary to assure safe flight. The USAF Safety Center and Air Combat Command are the key customers of this research.

Perceptual and Cognitive sciences support Air Force needs for selection and classification of personnel, improved instruction and training, and expert performance in an environment of increasing cognitive workload. Specifically, research on cognitive and psychomotor abilities seeks to develop tests of those abilities for improved computerized selection and classification batteries. This research, combined with studies of individual variation in ability, supports the development of technologies for evaluation of necessary job skills and development of computerized aiding systems based on human ability. Research on human-machine interfaces supports development of novel technologies for human interface, such as interfaces to virtual environments, in support of Air Force missions in unmanned air vehicles and in command and control. Research on intelligent tutoring systems supports technology goals of the Air Force to develop systems to implement both training and operational performance on the same equipment.

The primary customers of research in Perception and Cognition, the Air Force Armstrong Laboratory and the Air Education and Training Command (AETC), have benefited from recent findings of this program. Specifically, laboratory demonstration of novel computerized tests of psychomotor ability are under evaluation as new tests for personnel selection and classification. Also, the discovery of physiological indices of variations in cognitive workload are being studied for use with adaptive human interfaces. An intelligent tutor, based on research from this program is now being tested at the Air Force Academy and in several public high schools.

PROJECT 4113, SCIENCE AND ENGINEERING EDUCATION PROGRAMS

In addition to the research conducted under scientific projects, AFOSR supports programs, whose overall purpose is to stimulate scientific and engineering education and to increase the interaction between the broader research community and the Air Force laboratories. Special emphasis is placed on increasing the number of U.S. citizens with advanced degrees in science and engineering--key contributors to American industrial competitiveness and economic, as well as military security. Full participation by minorities is an integral objective of all our programs. AFOSR uses Defense Research Sciences (DRS) and University Research Initiative (URI) funds to support the Science and Engineering Education programs discussed in this section. URI is a DoD-wide program designed to strengthen the ability of universities to conduct research and educate scientists and engineers in technologies important to national defense. Each URI research program may include funds for graduate fellowships or grants, research instrumentation, and exchanges of scientists and engineers with other research organizations, particularly DoD laboratories. Fellowships and grants increase the number of graduate students in science and engineering. Upgrading university instrumentation enhance universities' research and education capabilities, as will scientific exchanges. The exchanges also increase contacts among universities, industry, and DoD laboratories, maximizing the contributions of defense research to the nation's military and economic security.

Summer Faculty Research Program (SFRP): The SFRP stimulates new relationships with university science and engineering faculty and their professional peers in the Air Force; enhances the research interests and capabilities of scientific and engineering educators in areas of Air Force interest; and develops the basis for continuing research of Air Force interest at the

faculty member's institution. More than 150 university faculty will be selected to conduct research at Air Force laboratories for up to twelve weeks in FY 97. Upon completion, approximately 60 mini grants (up to $25K each) will be awarded in FY 97 to continue promising SFRP research efforts at the institution of the faculty member.

Graduate Student Research Program (GSRP): GSRP is an adjunct to the SFRP. It permits graduate students to participate in research at an Air Force laboratory; stimulates professional association among graduate students, their supervising professors, and professional peers in the Air Force; furthers research objectives of the Air Force; and exposes graduate students to potential thesis topics in areas of Air Force interest. In FY 97, more than 100 graduate students will be selected to perform research for up to twelve weeks during the summer at Air Force laboratories.

University Resident Research Program (URRP): The URRP stimulates research cooperation between Air Force laboratories and institutions of higher education. Under the URRP, faculty members are brought into Air Force laboratories to conduct research for one year after which they return to their university with a broadened awareness of Air Force research needs and operations. Extension for a second year of residency is possible. For FY 96, twenty-two URRP slots are allocated to the laboratories.

USAF National Research Council (NRC) Resident Research Associateship Program: This program provides postdoctoral and senior scientists and engineers opportunities to conduct research compatible with the research interests of selected sponsoring Air Force laboratories. In this way, these researchers contribute to the overall research effort of the laboratories. This program is analogous to fellowships, associateships, and similar programs at the doctoral level in universities and other organizations.

The postdoctoral program is available to U.S. citizens and permanent residents and focuses on recruiting and developing America's most promising new PhD's. The senior associate positions, intended for internationally renowned researchers who have established their reputations over several years in academia, government or industry, are open to all qualified candidates of the U.S. and to citizens of other countries. Applicants must apply to the NRC and pass an NRC panel review to be considered for an award. Approximately 70 researchers will receive awards in FY 97.

National Defense Science and Engineering Graduate Fellowship Program (NDSEG): AFOSR participates in the National Defense Science and Engineering Graduate (NDSEG) Fellowship Program with the Army Research Office, the Office of Naval Research, and the Defense Advanced Research Projects Agency. The purpose of the program is to increase the number of U.S. citizens trained in science and engineering of military importance. The Air force will award approximately 25 fellowships in FY97.

GLOSSARY

ACC	Air Combat Command
AEDC	Arnold Engineering Development Center
AETC	Air Education and Training Command
AFCEE	Air Force Center for Environmental Excellence
AFSGO	Air Force Surgeon Generals Office
AFOSR	Air Force Office of Scientific Research
AFOTEC	Air Force Operational Test and Evaluation Center
AFSFC	Air Force Space Forecasting Center
AFSGO	
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AMC	Air Mobility Command
AOARD	Asian Office of Aerospace Research and Development
DARPA	Defense Advanced Research Projects Agency
ASC	Aeronautical Systems Center
ASPIRE	AFOSR Scholars Program Integrating Research and Education
BMDO	Ballistic Missile Defense Organization
C^3I	Command, Control, Communications and Intelligence
C^4I	Command, Control, Communications, Computers, and Intelligence
CFD	Computational Fluid Dynamics
CMC	Ceramic Matrix Composite
DCOR	Defense Committe on Research
DRS	Defense Research Sciences
EOARD	European Office of Aerospace Research and Development
ENO	Essentially Non Oscillatory
EPA	Environmental Protection Agency
FY	Fiscal Year
GEO	Geosynchronous
GSRP	Graduate Student Research Program
HBCU	Historically Black Colleges and Universities
HEDM	High Energy-Density Matter
HPM	High Power Microwave
IHPTET	Integrated High Performance Turbine Engine Technology
INS	Inertial Navigation System
IR&D	Independent Research and Development
JDL	Joint Directors of Laboratories
JSEP	Joint Services Electronics Program
LEO	Low Earth Orbit
LES	Large-Eddy Simulation
MBE	Molecular Beam Epitaxy
MEM	microelectromechanical
MI	Minority Institutions
MIT	Massachusetts Institute of Technology
NRC	National Research Council
NDE	Nondestructive Evaluation
POSS	Polyhedral Oligomeric Silsesquioxane
P&W	Pratt and Whitney
SAR	Synthetic Aperture Radar
RCS	Radar Cross Section
S&T	Science and Technology
SBIR	Small Business Innovative Research
SFRP	Summer Faculty Research Program
SMC	Space and Missile Systems Center
SPGs	Scientific Planning Groups
STTR	Small Business Technology Transfer Program
TAP	Technology Area Plan
TARA	Technology Area Review and Assessment
TEO	Technology Executive Officer
TSH	Thyroid Stimulating Hormone
UAV	Unmanned Air Vehicles
URI	University Research Initiative
URRP	University Resident Research Program

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Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

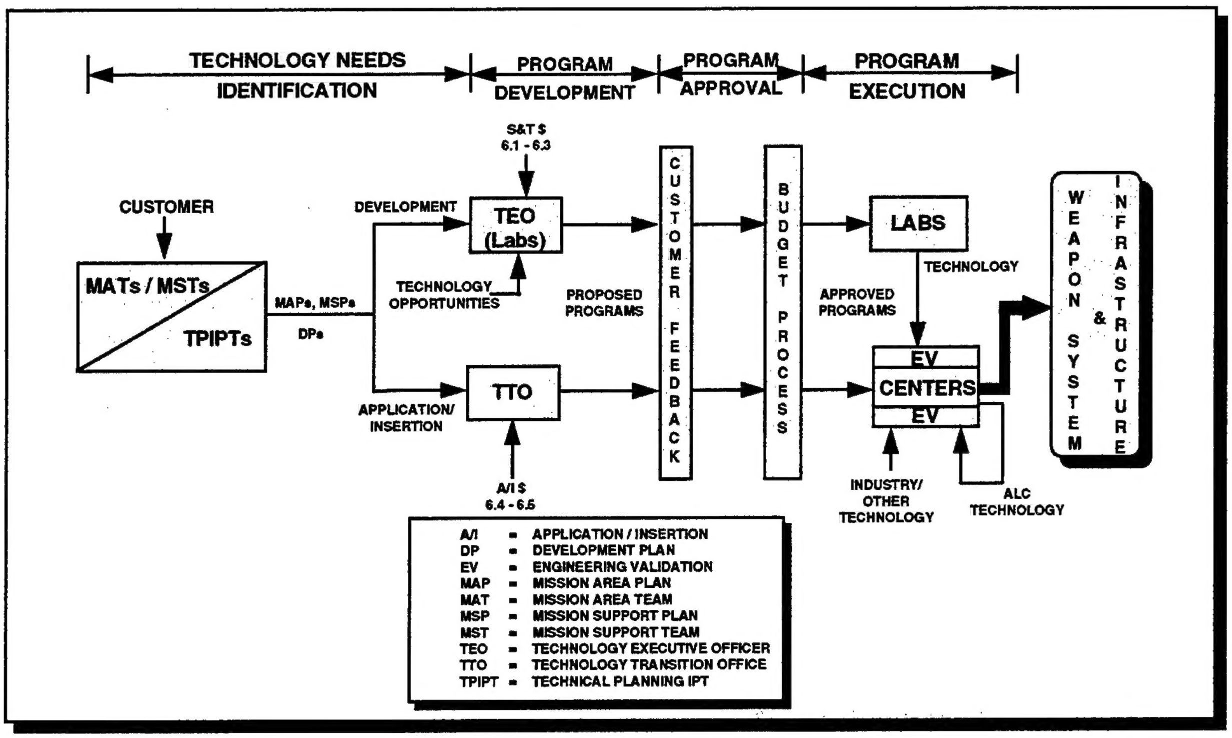

Figure 4. Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification** -- Collects customer-provided and customer-prioritized technology needs associated with both weapon systems, product groups and supporting infrastructure; then identify them by the need to develop new technology or apply/insert emerging or existing technology. These needs are derived in a strategies-to-task framework via the user-driven Modernization Planning Process.

- Phase 2, **Program Development** -- Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates the development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.

- Phase 3, **Program Approval** -- Reviews the proposed project portfolio with the customer and obtains approval for the portfolio through the budgeting process. The output of Phase 3 is the authorizations and appropriations required, by the laboratories and application/insertion programs, to execute their technology projects

- Phase 4, **Program Execution** -- Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STR, DSN 787-6777/8764, (513)257-6777/8764.